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COVER SHEET
Access 5 Project Deliverable

Deliverable Number: *HSI012*

Title: *Step 1: Human System Integration Pilot-Technology Interface Requirements for Contingency Management*

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Abstract:
This document involves definition of technology interface requirements for Contingency Management. This was performed through a review of Contingency Management-related, HSI requirements documents, standards, and recommended practices. Technology concepts in use by the Contingency Management Work Package were considered. Beginning with HSI high-level functional requirements for Contingency Management, and Contingency Management technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge of system failures and associated contingency procedures, and (2) the control capability needed by the pilot to obtain system status and procedure information. Fundamentally, these requirements provide the candidate Contingency Management technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how Contingency Management operations and functions should interface with the pilot to provide the necessary Contingency Management functionality to the UA-pilot system. Requirements and guidelines for Contingency Management are partitioned into four categories: (1) Health and Status and (2) Contingency Management. Each requirement is stated and is supported with a rationale and associated reference(s).

Status:

Document Status Work in Progress

Limitations on use:
This document is an interim deliverable. It represents the Human Systems Integration functions and performance requirements limited to enroute operations above FL430. Operations below FL430 and terminal operations have not been addressed in this document.

Step 1: Human System Integration (HSI) FY05 Pilot-Technology Interface Requirements for Contingency Management

Access 5
Technology Integrated Product Team
Human Systems Integration

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The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

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Executive Summary

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective. In FY05, several HSI products were developed to contribute to overall program objectives.

This product involves definition of technology interface requirements for Contingency Management. This was performed through a review of Contingency Management-related, HSI requirements documents, standards, and recommended practices. Technology concepts in use by the Contingency Management WP were assessed also.

Beginning with HSI high-level functional requirements for Contingency Management, and Contingency Management technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge of system failures and associated contingency procedures, and (2) the control capability needed by the pilot to obtain system status and procedure information. Fundamentally, these requirements provide the candidate Contingency Management technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how Contingency Management operations and functions should interface with the pilot to provide the necessary Contingency Management functionality to the UA-pilot system.

Requirements and guidelines for Contingency Management are partitioned into four categories: (1) Health and Status and (2) Contingency Management.

Each requirement is stated and is supported with a rationale and associated reference(s).

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Acronym List

ACS	Aircraft Control Station
BLOS	Beyond Line of Sight
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FRD	Functional Requirements Document
HALE	High-Altitude, Long Endurance
LOS	Line-of-Sight
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
WP	Work Package

1. Introduction

1.1. Background

Access 5 is a NASA-led project tasked to recommend the policies, procedures, and functional requirements that will ensure High Altitude Long-Endurance (HALE) Unmanned Aircraft Systems (UAS) operate as safely as other routine users of the National Airspace System (NAS). Four phases or "STEPS" are planned to systematically develop the necessary technology, policies and regulations to enable manufacturers to apply for Federal Aviation Administration (FAA) certification and approval needed to operate their civil UAS in the NAS. Current (FY05) effort limits focus to UASs that operate above 43,000 feet (STEP 1).

In order for UAS to be integrated into the NAS, it is necessary to identify the human systems integration requirements that ensure safe operations in the NAS. As a result, the Human System Integration (HSI) Work Package was established within the overall Access 5 program to address this objective.

In FY05, several HSI products were developed to contribute to overall program objectives. The FY05 HSI effort followed a standard, HSI process methodology that produced the following deliverables (Figure 1):

Deliverable 1: Human System Integration Step 1 Functional Requirement Document (FRD)

Deliverable 2: Human System Integration (HSI) Step 1 Design Guidelines for the Unmanned Aircraft System (UAS) Ground Control Station

Deliverable 3: High Altitude Long Endurance (HALE) Unmanned Aircraft System (UAS) Pilot Rating Criteria (Draft)

Deliverable 4: HSI Requirements and Guidelines for Experimental Certification of the Unmanned Aircraft System

Deliverable 5: Human Systems Integration Step 1 Pilot-Technology Interface Requirements

> Deliverable 5a: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Command, Control, and Communications in Unmanned Aircraft Systems

Deliverable 5b: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Collision Avoidance in Unmanned Aircraft Systems

Deliverable 5c: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for Contingency Management System in Unmanned Aircraft Systems

Deliverable 5d: Human Systems Integration Step 1 Pilot-Technology Interface Requirements for the Weather System in Unmanned Aircraft Systems

Deliverable 6: Human Systems Integration Support to Simulation and Flight Test for Step 1

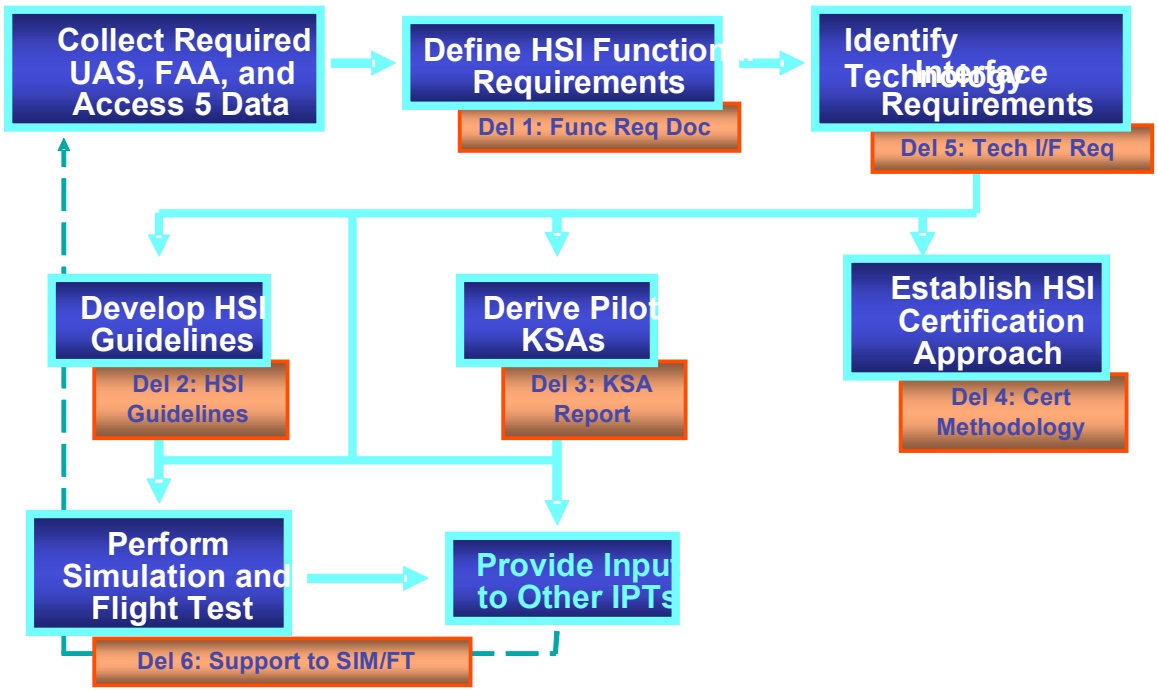

Figure 1. FY05 HSI Process and Deliverable Overview

2. Document Purpose

The purpose of this document is to define HSI technology interface requirements for Contingency Management.

Research of human capabilities and limitations known for Contingency Management was performed through a review of HSI requirements documents, standards, and recommended practices.

Technology concepts in use by the Contingency Management WP were assessed.

Beginning with the HSI high-level functional requirement for Contingency Management, and Contingency Management technology elements, HSI requirements for the interface to the pilot were identified. Results of the analysis describe (1) the information required by the pilot to have knowledge of Contingency Management, and (2) the control capability needed by the pilot to obtain Contingency Management information. Fundamentally, these requirements provide the candidate Contingency Management technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations. The results of the analysis describe how Contingency Management operations and functions should interface with the pilot to provide the necessary Contingency Management functionality to the UA-pilot system.

Requirements and guidelines for Contingency Management are partitioned into four categories: (1) Health and Status and (2) Contingency Management.

Each requirement is stated and is supported with a rationale and associated reference(s).

3. Scope

3.1. Ground Rules

3.1.1. Requirements are based on Access 5 Program Contingency Management Work Package (WP) requirements and concepts as well as HSI standards and recommended practices.

3.1.2. Requirements defined are for the Access 5 program, Step 1, which limits scope to Contingency Management only for flight above FL430.

3.1.3. HSI Requirement Verification for dynamic operations (e.g., pilot assessment and diversion in response to engine malfunction) requires verification in a dynamic environment (i.e., simulation or flight test). HSI Requirement Verification for static operations (e.g., procedure for engine malfunction) does not require verification in a dynamic environment, e.g., to be verified by analysis.

3.1.4. Requirements defined are independent of any design solution except those specified by the Contingency Management WP.

3.1.5. No distinction is made between Contingency Management requirements for line-of-sight (LOS) and beyond-line-of-sight (BLOS) HSI requirements

3.2. Assumptions

3.2.1. The pilot has all necessary control and display capabilities in the ACS to satisfy HSI requirements for performing contingency management.

4. Method

Research and documentation of human capabilities and limitations known for Contingency Management was performed through a review of HSI requirements documents, standards, and recommended practices. Sources examined include Aeronautical Information Manual; FAA regulatory and advisory material; FAA Human Factors Design Guide; other key research papers.

The technology concepts in use by the Contingency Management WP were assessed. Program documents were also used as reference material.[1]

For these Contingency Management technology elements, HSI requirements for the interface to the pilot (in the form of pilot information and control requirements) were identified. Fundamentally, these requirements provide the candidate technology concepts with the necessary human-related elements to make them compatible with human capabilities and limitations.

5. Technology Interface Requirements

The HSI FRD describes the highest level functional requirement for Contingency Management as follows: "The Human System Interface shall enable the pilot to manage contingencies."[2] In addition, a second high-level HSI functional requirement is applicable to this topic, "The Human System Interface shall convey information to the pilot to determine the health and status of the UAS."[3] Technology interface requirements in this document fall under these requirements.

Technology interface requirements are a necessary element of the HSI functional decomposition analysis of Contingency Management Functional and Performance requirements. The results of the analysis describe how Contingency Management operations and functions should interface with the pilot to provide the necessary Contingency Management functionality to the UA-pilot system.

They represent high-level, requirements for (1) pilot control of a Contingency Management and (2) information required by the pilot to understand the workings of the Contingency Management.

Requirements and guidelines are partitioned into two categories: (1) Health and Status and (2) Contingency Management.

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[1] Contingency Management Requirements Document, Revision D. March 2005.

Step 1: Functional Requirements Document, Preliminary Draft. May 2005

[2] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1, para. 2.4.4. July 2005.

[3] Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1, para. 2.1.3. July 2005.

Each requirement is stated and is supported with a rationale and associated reference(s).

5.1. Health and Status

5.1.1. ACS Display of Health and Status Data (Display Requirement). The ACS shall display health and status data for en route Contingency Management purposes.

5.1.1.1. Rationale. Health and status data shall make failures apparent and unambiguous to the pilot at the so the pilot obtains situation awareness of the vehicle state and in preparation to affect contingency management steps. In situations where automation failure would require user intervention, it is useful for the pilot to be warned that he or she will need to take manual control before the automated system fails. Information presented to the pilot should accurately reflect system and environment status in a manner so that the pilot rapidly recognizes, easily understands, and easily projects system outcomes.[4] [5]

5.1.2. Pilot Control of Health and Status Data (Control Requirement). The pilot shall have control capability to obtain access to health and status data.

5.1.2.1. Rationale. The pilot requires the capability to affect control of systems to obtain health and system status. Control capability includes access to systems and, if employed, a caution and warning and/or diagnostic system, that collects, integrates, and summarizes health and status information.[6]

5.1.3. ACS Alerting of Health and Status (Display Requirement). The ACS shall display health and status data alerts to the pilot.

5.1.3.1. Rationale. As the pilot will be involved in many ACS operations, it is not expected that the pilot will monitor the health and system status at all times. Humans are poor monitors over extended period of

[4] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002. para 3.8.2, 3.8.3, 3.8.4, 3.8.12, 3.12.4.
[5] Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 5364. Society of Automotive Engineers, March, 2003. para. 3.11.1, 3.11.2, 4.4.
[6] Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 5364. Society of Automotive Engineers, March, 2003. para. 5.1.

time. As a result, augmentation of pilot monitoring skill is required in the form of a master visual alert and/or aural alert to warn the pilot of a malfunction.[7] [8]

5.2. Contingency Management

5.2.1. ACS Display of Contingency Management Information (Display Requirement). The ACS shall display contingency management data to the pilot.

5.2.1.1. Rationale. The UAS shall provide the pilot with the ability to handle contingencies, emergencies and other abnormal conditions with the equivalent level of safety of manned aircraft. For critical software, systems, or equipment, there shall be a clear, step-by-step description of procedures to be conducted in the event of failure[9]. The pilot should be provided with sufficient information to diagnose warning system operation or contingency management functions.[10]

5.2.2. Pilot Control of Contingency Management Information (Control Requirement). The pilot shall have control capability to obtain access to contingency management functions.

5.2.2.1. Rationale. The pilot should be provided with sufficient controls to control warning system operation or contingency management functions.[11] [12]

5.2.3. Redundant Control Capability (Control Requirement). The pilot shall have redundant means to access systems and equipment that provide a critical function.

[7] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002. para. 7.1.1.1.
[8] Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 5364. Society of Automotive Engineers, March, 2003. para. 5.5.
[9] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002, para. 2.5.7.
[10] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002. para 3.8.15.
[11] Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 5364. Society of Automotive Engineers, March, 2003. para. 5.9.
[12] Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration. 2002. para 3.8.15.

5.2.3.1. Rationale. If a single type of pilot interface is provided for a critical system function, the system has the potential for a single point failure to compromise safety of flight. If UAS safety analyses determine that the TBD probability of such a single point failure can lead to an unacceptable reliability level, a redundant method of pilot interface should be provided to satisfy the required level of redundancy and reliability.

6. Future Work

6.1. Step 1 Lower Level Information and Control Requirements.

The requirements described in this document represent a high level definition for pilot information and control capability. Future work is required to continue this analysis to the level appropriate to the needs of the program and its customers, (e.g., the FAA). Lower level information and control requirements will provide the FAA and manufacturers with an appropriate level of guidance without restricting the flexibility of design. The level of detail required is exemplified in FAR 23.777, “Means must be provided to indicate to the flight crew the tank or function selected.” For Access 5 purposes, an analogous information requirement would read, “(For the top-level, Aviate functional requirement) A means must be provided at the ACS to indicate to the pilot the tank or function selected.” Once this level of detail is developed for each top-level functional requirement, the information and control requirements definition effort for Step 1 will be complete.

6.2. Step 2, 3, and 4 Information and Control Requirements.

After work for Step 1 has been completed, information and control requirements analyses are necessary for the succeeding Steps. The analysis will follow the functional requirements developed for these Steps and will focus on phases from takeoff to cruise and from cruise to landing. The analysis for altitudes between approximately FL180 and FL430 will require only minor additions to Step 1 results. Significantly new information will be produced from this analysis for the critical takeoff, climb, approach, and landing phases.

References

Aeronautical Information Manual. Federal Aviation Administration, Washington, D.C. February 17, 2005.

Contingency Management Requirements Document, Revision D. March 2005.

Human Factor Considerations in the Design of Multifunction
Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 5364. Society of Automotive Engineers, Warrendale, PA. March, 2003.

Human Factors Design Guide Update, Report Number DOT/FAA/CT-96/01. Federal Aviation Administration, Washington, D.C. June, 2003.

Step 1: Functional Requirements Document, Preliminary Draft. May 2005

Step 1: Human System Integration (HSI) Functional Requirements Document (FRD), Version 1.1. July 2005

Bibliography

Display Systems for Civil Aircraft, Aerospace Recommended Practice (ARP) 4153. Society of Automotive Engineers, Warrendale, PA. March, 2003.

WORKSHOP ON HUMAN MACHINE ISSUES IN UNMANNED AERIAL VEHICLES. George Mason University, Fairfax, VA. August and October, 1997.